py review copy review copy review copy review c

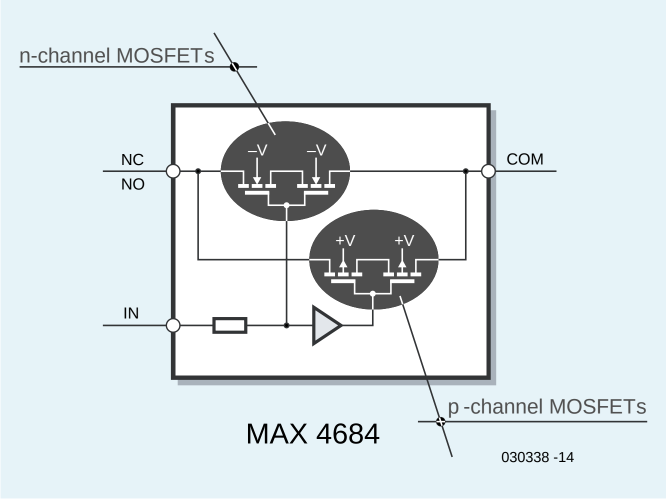


Figure 1. The switches consist of two MOSFETs (P- and N-channel).

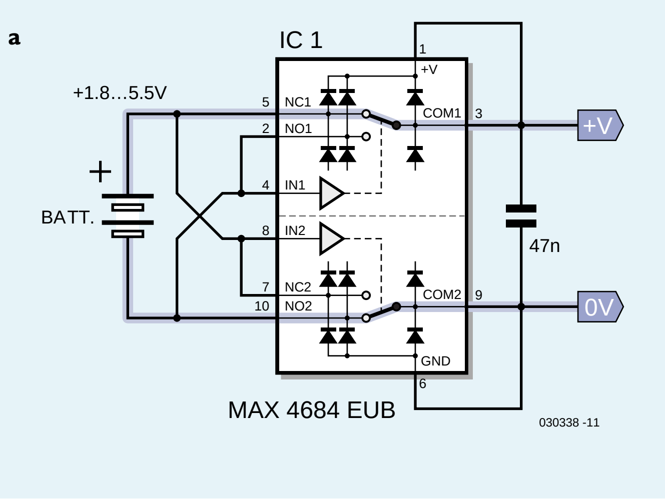


Figure 2. Current paths with correctly (a) and ...

Battery Polarity Protection

Look, no diodes, no relays!

K.-J. Thiesler

With battery-operated equipment there's always the risk of batteries being inserted the wrong way around. Although a diode or a bridge rectifier can be used to solve the problem, the down side is considerable energy loss through dissipation of the forward biased device(s). An energy-wise alternative is now available in the form of an integrated circuit containing two analogue change-over switches.

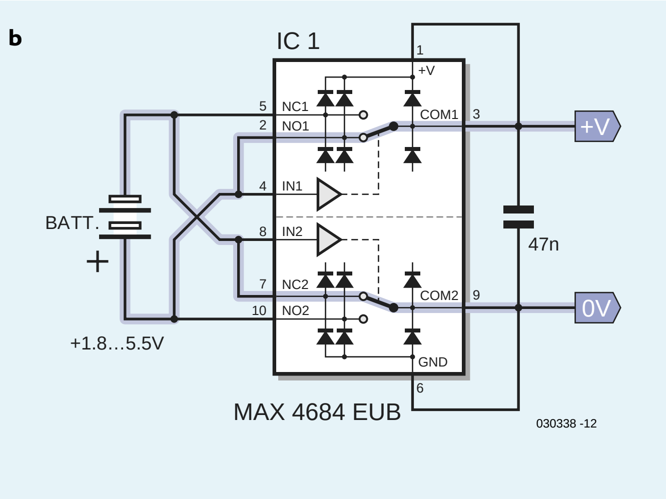
For sure, switching devices using CMOS technology have been around for a long time, but it was not until the requirements of mobile phones and portable test equipment forced chip designers to make substantial improvements to the venerable 4000 series of CMOS logic ICs. The 'retrofit' circuit described in this short article is based on the MAX4684 (from Maxim) and is capable of automatically swapping (or, if you like, correcting) the polarity of a battery set. The circuit can work from a voltage as low as 1.8 V, which may be supplied by two totally exhausted dry batteries, NiCd or NiMH cells in series.

The internal architecture of the chip as pictured in **Figure 1** shows two single-pole changeover switches realised using P-channel and N-channel MOSFETs. These devices are marked by a extremely low 'on' resistance, while acting very fast and being capable of carrying and switching high currents. Functionally, the two switches mimic a bridge rectifier fed with a direct voltage.

The MAX4684 not only protects the equipment being powered, but also arranges for an incorrectly polarized battery voltage to be swapped very quickly. The operation of the IC with the correct or the wrong supply polarity is illustrated in **Figure 2**. For clarity's sake, the current paths are highlighted. With no battery (or battery pack) connected, the two switches are in the 'inactive' position, so that the COM pins are effectively connected to NC (normally closed).

Figure 2a shows the switch positions when he right polarity is applied: control input IN1 (upper switch) is tied to the negative battery terminal and leaves the switch in its inactive position. The lower switch, however, toggles because IN2 is con-

opy review copy review copy review copy review



...incorrectly (b) polarized battery.

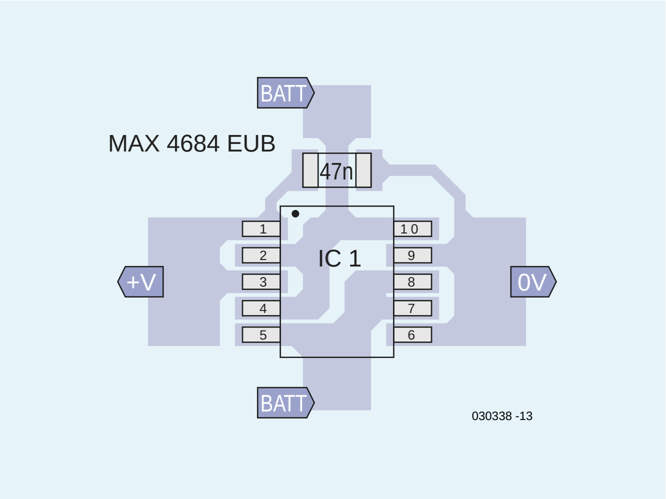


Figure 3. Suggested PCB layout with generous copper areas.

nected to the positive battery terminal. The switch now connects COM2 with NO (normally open), taking the battery negative terminal to the 0 V output.

The other drawing shows the effects of the battery terminals being swapped over. The upper switch changes state, while the lower switch remains in the inactive state.

Internal protection diodes at all inputs and outputs of the chip guarantee that the MAX4684 will always start properly the instant the batteries are inserted into the equipment. Before the relevant switch changes over, both outputs COM1 and COM2 (and with them, +V and ground) are short-circuited. The MAX4684 has a maximum switching time of 60 ns. Within that period, the internal protection diodes provide the supply voltage for the IC itself, independent of the battery polarity. The internal MOSFETs are driven and the switch toggles only when the relevant control input is connected to the positive terminal of a battery supplying at least 1.4 V. Only then does the correctly polarized battery voltage appear at the chip outputs.

The internal switching MOSFETs are controlled using a certain 'dead time' during which all switch contacts are opened. This so-called break-before-make mode of at least 2 ns prevents a short-circuit on the battery in case the output capacitor is still charged, supplying the IC during a battery change.

As opposed to conducting diodes with their virtually constant voltage drop, the voltage across the MOSFET switches is dependent on the current being passed. At just 0.3 Ω, the R_{DSon} specification at V+ = 1.8 V is remarkably low. At 5 V, the switch resistance drops to 0.2 Ω. The two switches and the protection diodes are capable of passing currents up to ±300 mA.
The above features make he MAX4684 an excellent choice for lots of equipment running off AA or AAA cells, including portable audio equipment, mobile test and measurement apparatus and cordless telephones.

Table 1 shows the maximum voltage drop across the two switches as compared with silicon and Schottky diodes in a bridge rectifier configuration.

The datasheet of the MAX4684 may be found at

http://pdfserv.maxim-ic.com/en/ds/MAX4684-AX4685.pdf

The IC is supplied in a miniature 10-pin µMAX case (3 × 5 mm). For space critical applications, the MAX4684 also comes in an even smaller 'UCSP' case which measures just 1.5 × 2 mm). **Figure 3** shows a suggested PCB layout for the MAX case. Finally, it should be noted that the MAX4684 can not be used to rectify alternating voltages.

(030338-1)

Table 1

Comparison between diodes and analogue switches (at 100 mA and 2.4 Vcc)

Component	Voltage drop	Dissipation P_{tot}
4 Si diodes	2 x 0.65 V = 1.30 V	130 mW
4 Schottky diodes	2 x 0.40 V = 0.80 V	80 mW
MAX4684	**2 x 0.02 V = 0.04 V**	**4 mW**
2 MAX4624	2 x 0.08 V = 0.16 V	16 mW
2 ADG819	2 x 0.05 V = 0.10 V	10 mW